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Where are the type 2 AGNs ?

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Abstract. Most of the energy of the X-ray background is contributed by sources with a hard X-ray spectrum, harder than the spectrum observed in nearby type 1 AGNs. The hard background contributors are conventionally identified with type 2 AGNs, obscured by circumnuclear matter both in the optical and in the soft X rays. However, preliminary results of identification programs seem to find systematically few type 2 AGNs in samples selected with obscuration insensitive criteria. We discuss this issue, and assess the various scenarios which are being proposed to solve the discrepancy.

1 The distribution of N_H.

Past hard X-ray surveys of Sy2s were strongly biased in favor of X-ray bright sources (according to all-sky surveys), which tend to be the least absorbed ones. We used BeppoSAX to observe an [OIII]-selected sample of previously unobserved, X-ray weak Sy2s. We found ([19], [12]) a large fraction of Compton thick objects, a result which confirms the bias against heavily obscured systems in previous surveys. We then merged all the available hard X-ray observations of Sy2s and extracted a complete subsample limited in *intrinsic* (i.e. unabsorbed) flux as inferred from the [OIII] narrow emission line [18]. This subsample is composed of 45 objects and the corresponding N_H distribution, shown in Fig. 1, can be considered the best approximation to the true distribution allowed by the available data. The most interesting result is that this distribution is significantly shifted toward large columns with respect to past estimates: most (~75%) of the Sy2s are heavily obscured ($N_H > 10^{23} cm^{-2}$) and about half are Compton thick. We have completed the N_H distribution by adding the Sy1s. Their number relative to the Sy2s is taken from Maiolino & Rieke [11], the relative populations of the N_H bins (only cold absorption is considered) are taken from literature data pertaining to the Sy1s of the Piccinotti sample [16]: this is a hard X-ray selected sample, and should not miss X-ray absorbed Sy1s unless they are Compton thick. We note a clear dichotomy between X-ray absorbed and unabsorbed sources, and a close correspondence between the X-ray and the optical classification, at least for these local, low luminosity AGNs.

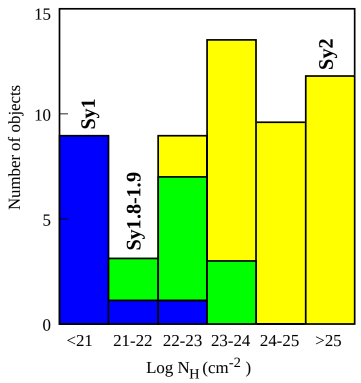

Figure 1: The distribution of absorbing column densities among Seyfert galaxies. From [18], with modifications.

2 The relation between optical and X-ray absorption.

If the obscuring torus has the Galactic gas-to-dust ratio, and the dust has the Galactic extinction curve, then the nuclear region of X-ray absorbed AGNs should suffer a visual extinction that is related to the gas column density by the formula $A_V = 4.5 \times 10^{-22}$ N_H (cm^{-2}). In general this is not the case: A_V is lower than what expected from the N_H measured in the X-rays. This was first pointed out by Maccacaro et al. [10], and is also required to fit the far-IR spectrum of AGNs [7]. We have collected a sample of Seyferts which exhibit at the same time X-ray (cold) absorption and optical or IR broad lines, not completely suppressed by the intervening matter. By assuming the standard extinction curve, and neglecting collisional or radiative transport effects, we can derive an estimate of the visual extinction. A preliminary result is shown in Fig. 2, where the distribution of A_V/N_H relative to the Galactic value is reported. With the exception of three low luminosity AGNs ($L_X < 10^{41.5}$ erg s^{-1}, shaded in the histogram), whose nuclear physics might be intrinsically different [8], most AGNs are characterized by a deficit of dust absorption, in agreement with early claims. At higher, quasar-like luminosities there are even more extreme examples of this effect: objects that, although absorbed in the X rays, do not show significant dust absorption in the optical and appear as type 1, broad line AGNs have been recently discovered in hard X-ray and radio surveys ([17], [20], [1], [5]).

The origin of this effect is not clear. An obvious explanation is that the dust-to-gas ratio is much lower than Galactic. However, large amounts of dust must be present in the vicinity of active nuclei, as inferred from their powerful IR emission. Alternatively, most of the cold X-ray absorption observed in these objects might be caused by broad line clouds intervening along our line of sight. However, if the low A_V/N_H is a property common to most AGNs, this interpretation would require a very large covering factor for the BLR whereas this is estimated to be only $\sim$10%. Dust in the internal region of the torus might be destroyed by the powerful nuclear radiation field, thus making the effective dust column significantly lower than the gas column. However, inside the sublimation radius a huge HII region would be created, with a covering factor much larger than observed (see also Netzer & Laor [15]). Another interesting possibility is that the dust extinction curve is much flatter than the Galactic one. The high density of the gas in the circumnuclear region of AGNs is likely to favor the growth of large grains which, in turn, should flatten the extinction curve. This effect is directly observed in the dense clouds of our Galaxy [4]. Large grains have also been proposed to explain the lack of the 10μm silicate emission feature in the mid-IR spectra of AGNs [9]. Within the context of the optical versus X-ray absorption, the effect of a flat extinction curve is twofold: 1) given the same dust mass, the effective visual extinction is lower, and 2) the broad lines ratio gives a deceivingly low measure of the extinction. A more thorough discussion of the whole issue is given in Maiolino et al. (in prep.).

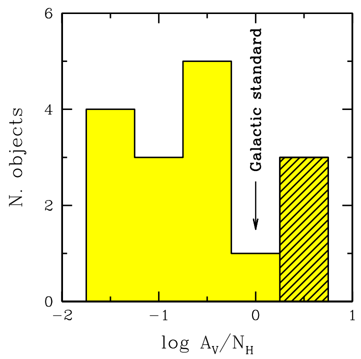

Figure 2: Distribution of the A_V/N_H ratio, relative to the Galactic value, for a sample of absorbed Seyferts. Three low luminosity sources ($L_X < 10^{41.5}$erg s^{-1}) are indicated with a shaded bin.

At the other extreme an increasing number of obscured powerful AGNs has been discovered by means of hard X-ray observations in galaxies which are optically classified as starburst or LINER. Probably, in these objects the obscuring medium hides the NLR as well as the BLR. Alternatively, the nuclear ionizing source might be completely embedded and obscured in all directions. The most spectacular case is the nearby (4 Mpc) edge-on galaxy NGC4945, whose nucleus is one of the brightest AGNs at 100 keV [3], but is heavily obscured in all directions. Indeed, optical to mid-IR observations were unable to detect any trace of AGN activity ([13], [14]).

3 Implications for the X-ray background.

Obscured AGNs are thought to be a key ingredient of the hard X-ray background (XRB, [21], [2]), and the distribution of N_H represents the main set of free parameters in the XRB synthesis models. The N_H distribution presented above can be used to freeze this set of parameters, under the assumption that it does not evolve with redshift. A detailed model that takes into account this constraint is presented in Gilli et al. [6]: although the shape of the XRB is well reproduced, the number counts are not, and suggest a larger number of X-ray absorbed AGNs as compared with the local Universe.

The deficiency of dust absorption with respect to the X-ray absorption, especially at high luminosities, implies a possible mismatch between the optical and the X-ray classification of the sources contributing to the hard X-ray background. In particular, some of the type 2 QSOs, which many models assume to make most of the hard XRB, could be optically "masked" as type 1 QSOs and be already present in optical surveys. On the other hand, the existence of heavily obscured AGNs in powerful IR galaxies which optically are *not at all* classified as AGNs suggests that a fraction of ULIRGs and SCUBA sources might host some of the type 2 QSOs which are needed for the hard XRB.

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